The A B C

OF

Railroad Signaling

A Lecture delivered before the Harvard School of Business Administration

BY

W. H. ELLIOTT

Signal Engineer N. Y. C. & H. R. R. R.

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PREFACE.

This little book is intended to conduct the student, engineer, or railroad officer who desires a working knowledge of Signaling merely to the entrance to its inner workings and apparently mysterious applications. It is put forth to serve as the first step—the A B C of Railroad Signaling.

It is the earnest hope of the publishers, that, should the learner desire to penetrate further, his way will have been made easier to travel, in a measure, at least, by the reading of this first simple presentation of the broad principles of the subject.

July, 1909.

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RAILROAD SIGNALING

Railroad signaling is the art of so installing and operating signals that an engineman may properly control the movements of his train by the signal indications displayed. During the day the signal indications are given by the position of the signal arm, and at night by the color of a light. Owing to the heavy and complicated construction required and the difficulty in determining the relative location of a signal arm on a pole, good practice limits the number of arms used on a single pole to three. Of distinctive lights that may be used to give the signal indications, there are but four, namely, red, yellow, green and purple. Good practice in the safe and rapid movements of trains has shown it is

desirable to give, either by signal arms during the day or by colored lights at night, fourteen primary signal indications which concern the immediate movement of the train, and seven secondary indications which have to do with the future control of the train. It will, therefore, be seen that in arranging the signals and assigning a specific meaning or indication to each aspect the task has been no easy one, for if safe operation is to be secured and mistakes are to be eliminated, each indication must be definite and easily distinguishable from all the others.

The practice of the roads in the United States in the meaning assumed to be conveyed by various signal aspects, varies materially, and at the present time many roads are changing their practice in the endeavor to secure a uniform system of signal indications. It is, therefore, apparent that signaling is not an exact science. Those taking up the subject at this time must not be surprised at finding that different signal aspects on different roads are assumed to mean the same thing, or in technical language, to give the same indication.

Primarily signaling has to do with conveying to the engineman the information necessary for him to safely and properly control the movement of his

Hall disc signal indicating "Clear".

train. It is assumed that with this accomplished the engineman must do his part and control the train in accordance with the signal indications displayed. Various types of signals are still in use in this country, the semaphore arm, the disc, and the revolving banner type of signal. Of these the semaphore is now recommended as the standard. The semaphore signal, as will be seen, consists merely in the attachment of an arm or blade four feet long to a spectacle which is arranged near the top of a pole so that the arm will stand normally in the horizontal position, projecting to the right of the pole, as seen from an approaching train. To give the indication to proceed, the arm will be moved downwardly for signals working in the lower quadrant, and upwardly from the horizontal for signals working in the upper quadrant. Signals of the lower quadrant type have been the standard in the past, and the upper quadrant signals may be said to be the type of the future. Six of the larger roads of the country have adopted the upper quadrant signals as a standard and it is probable other roads will do the same in the near future.

Signals of all kinds are divided into two general classes: block signals, which control the use of a section of the track and show whether or not the

track is occupied, and interlocking signals, which have to do with the switches in a track and the particular route which is set for a train to take. With interlocking signals separate arms to a maximum of three are used for indicating any one of all possible

Mechanically interlocked home semaphore signals and a disc signal on a signal bridge. Semaphores in "Stop" position. Disc signal seen from rear.

routes, the upper arm for the main line or through route, the second arm for a limited speed route from one track to another with traffic, and the third and lowest arm for any one of all possible routes. With block signals, but two arms are used on a pole, the upper arm to indicate immediate and present con-

trol as to whether or not the train may pass the signal, and the lower arm to repeat the indication of the upper arm of the next signal in advance.

In block signaling the track is divided into a number of sections of considerable length, which sections are termed "blocks." At the commencement of each section a signal is placed, which is called a block signal. This signal is also known as the home signal, as it governs the movement of the train when entering the block. The signal which is used to repeat the indication of the next signal in advance is called the distant signal. For blocks that are one and one-half miles in length, or shorter, the distant signal is usually placed on the same pole with the home signal. When the blocks are longer than this, the distant signal is usually placed on a separate pole located about 3,500 feet in the rear of the home signal. This distance for level track is sufficient to enable a train traveling at a speed of 75 miles an hour, or less, to be stopped in running between the distant and the home signal, a requisite necessary for the safe and proper control of a train. When the home signal arm is in the horizontal position, "stop" is indicated. When the arm is 60 degrees below the horizontal or 90 degrees above the horizontal, "proceed, block is clear" is indicated. If

there are two arms on the pole, the upper arm is the home signal, and when in the proceed position indicates the train may proceed through the block to the next signal in advance. If the upper arm and the lower arm are both at clear, an indication is also given that the next home signal or the one at the

Electrically operated interlocked semaphore signals on a signal bridge. Upper blade indicates "Proceed on main line route".

commencement of the second block in advance is at clear and the train may proceed for two blocks in advance. In this way an engineman finding both arms of a signal at clear may proceed at speed, knowing that a distant signal will be passed which will give ample warning in time to enable him to properly control the speed of the train, should there be a signal in advance which is indicating stop.

Block signal systems are divided into three general classes:

1—The telegraph system, so named from the means employed in conveying from one station to the next information as to the state of the block.

2—The controlled manual system, so named from the fact that while the signal at the entrance to the block is cleared by a signalman, the clearing of the signal is controlled by the signalman at the outgoing end of the block, who must first give an unlock for the signal before it may be cleared for a train to enter the block.

3—The automatic signal system, so named from the fact that the signals are operated by some form of power, and being automatic in action, do not have to be worked by an attendant. The automatic systems are further classed according to the power employed to work the signals. With the electro-pneumatic system compressed air is the power used and electricity is employed to control the action of the compressed air. In the electric system direct current is used to energize the motor which turns and clears the signal, and also to work the relays and circuits of the controlling system, causing the signal to give the proper indications. In the alternating current electric system the controlling and

the motor circuits are worked by alternating current which must be obtained from a power house and be distributed on a specially arranged wire line.

Automatic block signals, electrically operated, upper blade indicates "Block ahead is clear",—lower blade is a distant signal for the upper blade on the next signal ahead, repeating its position. In the illustration the lower blade indicates that the second bock ahead is "Clear".

In the telegraph block system signal stations are located at convenient points to give the desired spacing of trains, and signals are placed to govern trains moving in each direction. As the signal to govern trains moving in a certain direction must project to the right of the pole, as seen from an approaching train, the two signal arms required to govern for both directions, where there are but one or two tracks, are sometimes placed on the same pole. A stand with a lever for each signal to be worked is placed in the station office and a telegraph wire is installed with the necessary instruments. With the telegraph block system distant signals are not usually installed, but where the operating conditions, such as a down grade track, an obstructed view of the signal, or the high speed of trains make it necessary that the engineman be informed in advance of the indication given by the block signal, a distant signal is often used.

With the equipment installed at each station and signalmen provided, the blocking of trains must be performed in accordance with the rules which each road adopts for its own use. On the approach of a train to a station the signalman examines the block record on which is marked the time each train enters the block, passing the station in the rear, the

time the train passes the station at which the signalman is located, and the time the train passes the station in advance, and if the block is shown to be

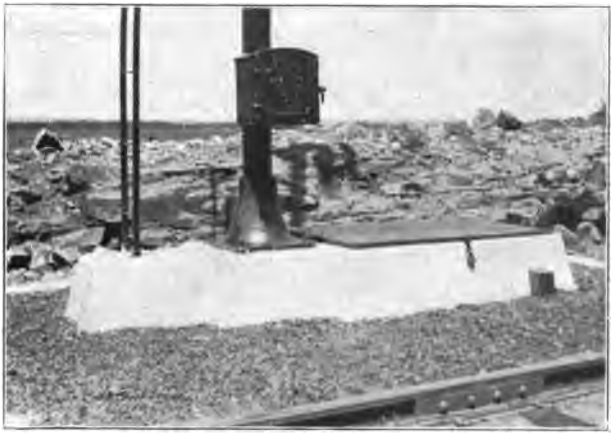
Single blade automatic block signal giving "Clear" indication. This indication is in the lower right hand quadrant.

clear, that is, that the last train entering has been reported as leaving the block, then the signal is cleared and an approaching train may enter the block without reducing speed. As soon as the head end of a train has passed the signal, the signalman reports to the next station in advance the time, together with the number of the train. On the rear of the train, which is the car having the markers, passing the signal and traveling for 300 to 500 feet beyond the signal, the signalman reports to the man in the station in the rear that the block is clear. The time so reported is marked on the block record and on the train being reported as having passed the block station in advance, the fact must also be marked on the block record and the block will then be clear and another train may be admitted.

On single track it is necessary, before a train may be admitted to the block, to communicate to the signalman at the other end of the block to have him lock his signal in the position indicating stop, and to keep trains from entering the block from that direction until the expected train has arrived.

Where there are more trains to be run than may be permitted to pass on a single track, if one train only is allowed to occupy a block at a given time, it is customary on many lines to allow two trains to

be in a block at the same time. If one train only is allowed in a block, it is termed "absolute blocking." If two or more trains are permitted in a block it is said to be "permissive blocking." Permissive blocking is, in many instances, allowed in the running of



Base of an automatic block signal showing one method of constructing a foundation for the signal post. The box on the post contains the relays which govern the signal mechanism. The primary batteries which furnish current for the operation of the signal are housed in the foundation. Bond wires for the electrical connection from one rail to another may be noted in the lower right hand corner of the picture.

freight trains, but where a passenger train is concerned absolute blocking is almost always enforced, except in a case of an emergency. While permissive

blocking may be allowed on certain roads as a general practice, it is usually the case that when the weather conditions are bad on account of fog, snow or storms, the dispatcher may require that absolute blocking be observed. It may also be required that on portions of the line where the operating conditions are difficult absolute blocking may be enforced. The practice on the various roads regarding this differs materially, and it must be assumed that each road follows the practice it finds best to meet the existing conditions.

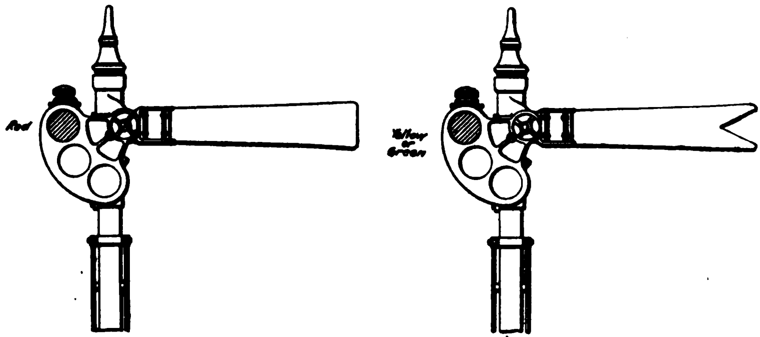
With telegraph blocking a check upon the work of the signalman is not provided, and if he should fail to enter on the record the time of a train entering or leaving a block, two trains may wrongly be allowed to be in a block at the same time, both having received clear signals, indicating there was no other train in the block. A signalman may fail, through error or neglect, to communicate with the man at the other end of the block and may admit a train when the block was occupied. Wherever men are employed they will occasionally make mistakes, and to guard against a thing of the kind happening and possibly an accident resulting, the controlled manual system of blocking trains has been perfected. In this system an electric lock is placed on the

The mechanism of the Union Switch and Signal Company's Style B automatic signal. The rods are connected to the semaphore. It will be observed that were the mechanism shown in use, the semaphore to which the rear rod is connected would be in the "Stop" position, while the semaphore to which the rod in the front of the picture is connected would be indicating "Clear".

lever working the signal at the entrance end of the block, and an electric switch with which the lock circuit is controlled is placed at the station at the outgoing end of the block. When the circuit to the lock is open, the lever is locked and when this circuit is closed, the lever is unlocked. This makes it necessary that the two signalmen, the one at the entrance and the other at the outgoing end of the block, must co-operate in the clearing of the signal. The signal at the entrance of the block is manually operated, the same as with the telegraph block signal, but is also controlled by the man at the other end of the block through the working of the electric lock, hence the derivation of the name by which the system is known.

Although controlled by both signalmen, it would be possible for both to work together and wrongly clear the signal if some additional apparatus was not provided to prevent this. To guard against this being done, controlling track circuits are installed at each station and a block instrument has been designed which, when a train passes a signal and enters the block, opens the circuit to the lock on the signal lever and prevents the second clearing of the signal until the train has passed over the track circuit at the outgoing end and therefore out of the

block. To insure that the electric lock may become effective and lock the signal in the stop position, the circuits are so arranged that before the circuit to the lock of the station in the rear may be completed, the signal at the station from which release is given must first be put in the stop position. Immediately



Home signal indicating "Stop". Distant signal indicating "You may expect to find the next home signal indicating either 'Stop' or 'Clear'."

this is done the electric lock on the lever will drop into the notch in the lever, locking the lever, and with it the signal, should the block in advance be occupied.

Owing to the convenience and quickness in handling, communication between block stations of the controlled manual system is generally had by means

of bells, a proper code being arranged. On a train approaching a block station the signalman rings the next station, requesting an unlock of his signal. If the block is clear the signalman at the station in advance works the block instrument by pulling the plunger lever which closes the circuit to the lock of the station in the rear, indicating to that signalman that the signal may be cleared. On plunging, the card or dial in the block instrument which previously indicated "free" is changed to show the word "locked," indicating that the instrument is locked, and, permission having been given for train to enter the block, a second permission or plunging action cannot be performed. When the signal has been cleared and the train enters the block, the circuit to the lock is broken and the indicator of the block instrument in the station in advance, which previously stood at "locked" now drops to show "train in block." This indicates to the signalman in that station that a train is approaching and he proceeds to get an unlock from the station in advance and to clear the signals at his station when the unlock has been received. On the train passing off of the track circuit and out of the block, and the signalman has returned the home signal to the stop position, the card of the block instrument drops to

"free" and the signalman may again plunge and release the signal at the station in the rear for another train to enter the block.

As a further check on the work of the signalman

Upper quadrant signal indicating "Proceed at limited speed".

to prevent his making a mistake, it is customary to put an electric slot or releasing device in the signal connection to insure that the signal will go to the stop position automatically when the train passes the signal and thus force the signalman to restore

the lever to the normal position to again get control of the signal, in which case the block being occupied, the electric lock will hold the lever and prevent the clearing of the signal again until the block is clear.

The controlled manual system without a track circuit from one block station to the next may occasionally fail and a wrong clear indication be given. If a track circuit is installed the manual control of the signals except for special situations, may as well be eliminated and the signals made automatic in action with less complication in apparatus and fewer failures. The blocks may then be made short to allow for a maximum traffic, and when there is a failure, the detentions of trains are reduced to a minimum compatible with safety. In the automatic system the signals are power operated, and in the more common forms are worked by direct current or by compressed air. With either type, the control of the power is effected by means of relays, a very common form of which is found in the mechanism of the electric bell, which, instead of being fitted with a clapper and striking a bell, is provided with contacts which, in the case of the motor operated signal, open and close the circuit to the motor, causing it to move the signal arm to the position to give the proceed indication when the motor is energized, and

to allow the signal to assume the stop position when the motor circuit is open. The circuit of this motor control relay and the corresponding circuits are known as line or signal circuits to distinguish them from the track circuits.

A double automatic signal location. The train on the right hand track has just entered the block, and the signals have, therefore, just assumed the "Stop" position. Signals on the left hand are indicating "Two Blocks Clear" for a train running in the direction opposite to that of the train shown.

In the automatic signal system the control of the signal circuits and therefore of the signals and the system, is obtained through the operation of a track circuit of low potential of which the rails are made to form a part. The track is divided into sections of a length suitable for track circuit purposes, 3,000 feet being possible where the track is gravel ballasted, and 5,000 feet for a track having rock ballast. One section is separated from the other by means of an insulating rail joint, placed at the end of each rail of each section. At one end of the section a battery is placed, usually consisting of two gravity cells connected in parallel to give the maximum output in quantity of current or amperes, at a minimum voltage. The rails of the track are connected together electrically by two wires placed at each joint, these being known as bond wires. At the other end of the section of rails from the battery end, a relay is placed having connections to the ends of the rails. The current from the battery passes from the positive pole to the rail to which the copper element is attached, through that rail to the other end of the section, from this rail to the relay, through the relay, energizing it, to the other or negative rail and back through that rail to the negative pole of the battery. The voltage of the battery is made low to reduce to

a minimum the leakage between rails, as the insulation afforded by the ties is very low, particularly in wet weather. The resistance of the relay is also made low, generally four ohms, to insure that sufficient current will pass through the relay to energize it when the track is not occupied.

Electrically operated interlocked home signals governing a terminal track arrangement. All signals are indicating "Stop".

With the relay energized the armature is attracted, closing the contacts and completing the line or signal circuit, which in turn energizes the motor control relay, closing the motor circuit and causing it to operate to clear the signal. If, with the signal at clear, a train passes the signal, running on to the track circuit, the wheels of the train offer a path of practically zero resistance, and the current from the

battery flows from one rail to the other through the wheels of the train, shunting the relay, and de-energizing its armature, causing it to fall away from the poles and open the line or signal circuit. On the opening of this circuit, the relay controlling the circuit to the motor and signal mechanism is de-energized, releasing the mechanism and causing the signal to indicate stop, which when interpreted means that there is a train in the block.

Where there is but one track circuit and one signal, the track relay may be made to control the signal motor circuit direct, but if there are two or more track circuits in the block if distant signals are employed, or if other agencies are used than a motor to work the signal, the track relay does not possess sufficient power, owing to the weak current it is necessary to use, and line or signal circuits must be used for this purpose. These line circuits are employed to ring bells at crossings, work indicators, repeaters and others of the numerous auxiliary devices which are used in connection with an automatic signal system.

In the electro-pneumatic system compressed air at 75 pounds pressure is used to work the signals In other respects the system is the same as the direct current electric system. The signal relay by

which the working of the signal is controlled is, in this instance, not provided with contacts but in-

The automatic disc signals shown here govern the block immediately ahead and the semaphore arms repeat the positions of the next home signals in advance. The first and third signals counting from the left govern trains running on the first and third tracks toward the bridge in the background, while the second and fourth signals govern trains running on the second and fourth tracks in the opposite direction.

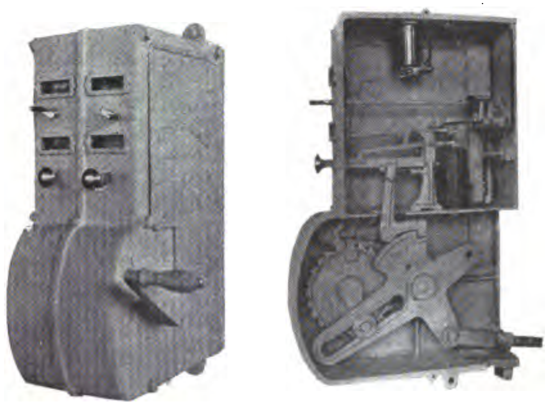
stead, the armature is made to act as a pin valve to supply or to shut off the air to a cylinder, the piston of which is connected to the signal.

When air is admitted to the cylinder in the electro-pneumatic system the signal is made to assume the clear position. When the air supply to the cylinder is shut off and an escape to the atmosphere opened, the weight of the signal forces the air from the cylinder and the signal is changed to the horizontal position indicating stop.

With the electro-pneumatic system is is necessary that compressors be put in at every 25 or 30 miles of road and the compressed air distributed by a main pipe line. Where signals are located, a tap on the main pipe is made and connections to the signals are put in. Care has to be used in collecting all condensed water from the compressed air.

With the introduction of electric train service on steam operated railroads and the rails are used for the return of propulsion current to the power house, it is not possible to use battery operated track circuits to control the signals, and the alternating track circuit has been designed to answer the same purpose. In this circuit, the relay consists merely of an induction motor, the armature of which on revolving is made to close or open contacts to

control signal or motor circuits. The current for the track circuit being alternating must be obtained from a power station and the current distributed on a suitable line at a comparatively high voltage. Where there are signals to be worked and track



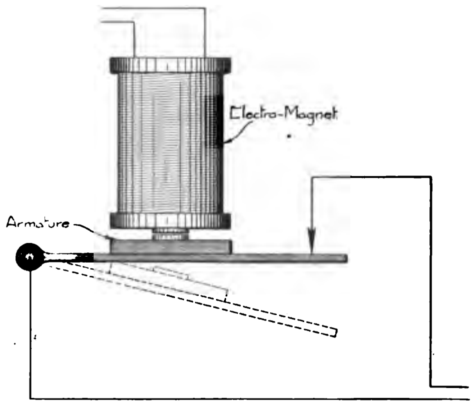
Three-quarter and sectional view of the controlled manual signal mechanism made by the General Railway Signal Company. The signal is cleared by manipulation of the handle shown in the first picture, under the proper circumstances.

circuits to be operated, a transformer is connected to the line which transforms the high to the lower voltage current required. The ohmic resistance between the rails being low, a low voltage current is

used, although there is no objection to using slightly higher voltages with alternating current than with direct current, the leakage with the alternating current being much less. The particular voltage used in each case will depend on the length of track circuit and the insulation between the rails, the current potential varying from 1 to 12 volts or even higher, when necessary. Insulating splices are used to separate the track circuits one from the other, the same as with D. C. circuits, but as the rail must be used for the return of propulsion current, a path for this current must be provided while isolating or keeping separate each track circuit current. This may be done in a number of ways, the most common being to use one rail for the signal A. C. circuit alone, and the other rail for the other side of the track circuit and also for the propulsion current, in which case, this common rail is continuous and insulating rail joints are put in only in the rail given up for the signal track circuit.

The other arrangement of A. C. track circuit that is in common use is the one where both rails of the track are used, both for direct current propulsion and for alternating current track circuits. At each end of the track circuit a reactance bond is placed having terminals which connect the bond

with the ends of each of the track circuit rails. This bond is of comparatively low resistance to the passage of the propulsion current, which therefore flows almost as readily as if the rail were continuous



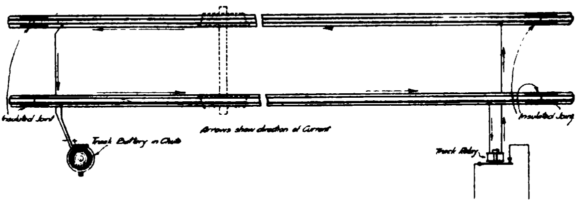
Sketch showing in full lines the position of a Relay armature and the arrangement by which a circuit is closed when the relay electro-magnet coils are energized by the passage of the current through them, and in dotted lines the position of the armature and the broken circuit, when the relay coils are de-energized.

and without insulating joints. To an alternating current the bond is reactive giving a resistance in proportion to the number of turns in the coil and to the size of the iron core. By making the reactive resistance in the bond sufficient to give a

difference in potential at the end of the track section sufficient to work the relay, the relay will be operated the same as if there was no electrical connection between the ends of adjacent track circuits, and both rails of the track may in this way be successfully used both for propulsion and alternating current track circuits.

Where the propulsion current is alternating as well as the current used for track circuit purposes, it is necessary that the two currents differ in frequency of alternating sufficiently to prevent the propulsion current from having any effect on the track circuit relay, the armature of which must respond only to the track circuit current. A current of 25 cycles per second is the one usually employed for propulsion current, and by making the frequency of the track circuit current 40 cycles or 60 cycles per second the impulses to turn the armature of the track circuit relay, while occurring at the same instant for at least one cycle out of the total given in one second, will so soon change and be opposing each other in pull on the armature, that the armature will react and will be turned only by the current having the frequency for which the motor is arranged to work.

With a constant supply of current at all points of the line, such as is necessary where A. C. track circuits are installed, it is economical and usually the practice to use this current for all circuits and dispense with batteries and the care necessary in their maintenance. Alternating current is therefore used to work the signals, the signal circuit and



Sketch showing the principal connections for a track circuit in a single section, the arrows indicating the direction of the current flow.

practically do all the work of operating the entire signal system. As a failure of the power supply will put the entire system out of service, it is necessary that provision be made for a constant supply of current. Complete equipment in duplicate for the principal parts is usually installed in the power stations and every precaution is taken to prevent a drop in the voltage or a stoppage of the current.

The block signaling of a line of road requires a

knowledge of the traffic, grades, the location of switches, curves, stations and objects which will obstruct a view of the signals from approaching trains. As near as practicable, the signals should be located to permit trains running at speed to follow each other through the consecutive blocks in practically the same interval of time. If the blocks were made of equal length, trains would be spaced equal distances apart, but very unequally spaced as to time where the grades in one case were ascending and in the other, descending. One train would then often overtake the other, causing delay and a useless expenditure of fuel. The average length of block should be based on the number of trains it is desired to run in a given time. Blocks one mile long are considered good practice for roads having as many as 30 trains per track per day. Longer blocks may be and are used up to as much as 3 miles in length, but owing to the time lost by a train in running through the block when there is a signal failure, it is not advisable to make the blocks longer than 2 miles.

Having determined on the average length of block desired, and before locating the signals in the field it is best to draw a plan of the tracks and make

a proposed location of the signals, in which the length of the block will be increased in the proportion that the grade of the track is descending and shortened for an ascending grade. Where there are switches, the signals should be located, if practicable, in the rear of the switch and at curves, so

An interlocking tower governing a complicated terminal yard and depot arrangement of tracks.

that the signals may be seen by an approaching train. It is also desirable that the signals for different tracks be placed near the same points to economize in cost of installation and maintenance. The exact location of the signals along the track should be made only after the ground has been

looked over carefully and all of the varying elements which enter into the problem have been considered. Poorly located signals will result in an uneven spacing of trains and render difficult the work of the engineman in properly controlling the movement of his train.

While it is comparatively easy to locate signals where the blocks are a mile in length, the problem becomes difficult where the blocks are made short to accommodate a maximum traffic. In such cases the shortest length of block that may satisfactorily be used is that of the braking distance for the speed at which trains are required to run. In every case it is necessary for safe operation that the distant signal be placed far enough from the home signal for a train running at the maximum speed allowed to come to a stop in the distance between the distant and the home signal. If this is not done, then in bad weather, when the distant signal cannot be seen until the engineman arrives at the signal, he must either slow down to be able to stop at the home signal, should the distant signal be indicating caution, or else, run the chance of going by the home signal, should it be indicating stop, with the possibility of there being a collision should there be another train in the block.

With the braking distance determined for the maximum speed allowed, and the signals so located, the time interval spacing between trains will be a matter of the time it will take a train to run through the block, plus the time required to run the dis-

View of train dispatcher's office showing operators using telephone apparatus adapted to train dispatching.

tance between the distant and home signals, plus the time required for the train to run its entire length, the spacing of trains for the braking distance being dependent on the position of the head end of the train, and the clearing of the signals, after

the passing of a train, being controlled by the rear end of the train. In addition, time must be added for the home and the distant signals to change from the stop and cautionary to the clear position and the time required by the engineman to observe

A mechanical interlocking plant, showing lead-out in front of tower.

that the signals are indicating proceed and to govern the train accordingly. This last interval of time may be considered as the personal equation of the engineman and will vary with different men. With comparatively slow speed trains, 5 to 8 seconds should be sufficient, and for fast trains 8 to 12

seconds interval will be required by the engineman to assure himself that he may continue to run the train at speed, after observing that the distant signal has changed to indicate proceed. With allowances made for each of the above mentioned ele-

Interior of tower, showing levers and indicators. The interlocking machine is of the vertical locking type.

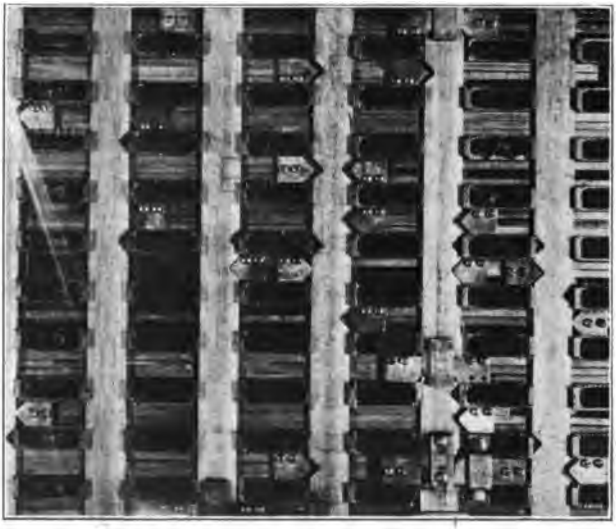
ments which enter into the problem of determining the maximum number of trains that may be run in a given time, and taking the sum of the whole, a chart may easily be plotted showing the time spacing of trains for various speeds and lengths of block. In making plans for and discussing with the operat-

ing department the effects on the traffic of any proposed installation of signals, this chart will be found of great convenience to the signal engineer.

The block signals which have been described indicate the condition of but one track, showing whether or not this track is occupied, and if it is proper for a train to proceed. Interlocking signals, on the other hand, give additional information. They show the route which a train may take, indicate the speed at which a train may run, show if it is proper for the train to proceed, and may also be arranged to show if the track is unoccupied. The necessity for indicating the route, and the speed at which a train may run, is evident where there are facing switches in a main track. Interlocking signals were first used to indicate the route which a train would be required to take, but with the installation of the narrow angle frogs and long crossovers or turnouts, enabling trains to run through switches at comparatively high speed, it has become necessary to give a separate signal indication to enable an engineman to assure himself it is safe to run at the speed possible through these long switches.

In order to insure that the proper route will be set when a certain signal is cleared it is necessary

that the switches be controlled and worked by the person working the signals governing such route, and that this end may be secured, interlocking ma-



The interlocking itself. The pointed dogs sliding into and out of the V-shaped notches in a certain pre-determined order prevent mistakes on the part of the lever man.

chines have been designed which, by interlocking one lever with the others which control the movements of the signals and switches, render it impossible to set the route and at the same time clear

signals for movements on any two tracks which conflict and may result in two trains being brought into collision with each other. In addition to the interlocking between the levers, it is necessary to

A close view of a lead-out of the rocker-shaft type.

insure correspondence in working between the levers controlling a signal or switch and the movement of the signal or switch itself. If this were not done the lever might be in one position, allowing a certain route to be set up, and the signal controlled

by such lever might be in the clear position, giving permission for a movement that may conflict with a train moving over the route set. This corre-

A pipe-run. Each pipe extends to a switch or signal, or lock, and is connected to a lever in the tower, transmitting the movement of that lever to the proper function.

spondence of the movement of the controlled function with the lever is assumed in the case of mechanical interlocking connections, and is given by

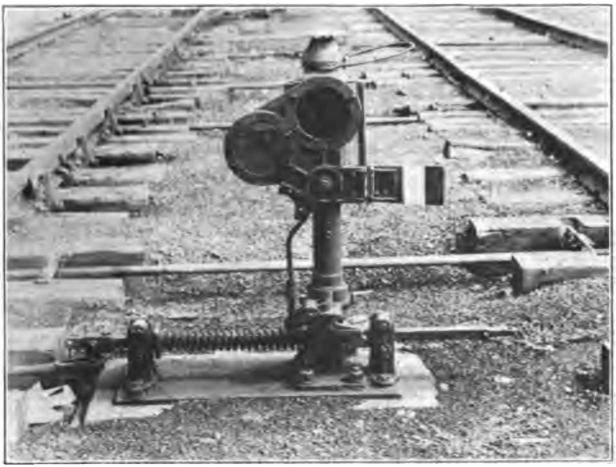
special indicating devices in the case of power operated interlocking signals and switches.

Interlocking signals are divided into three general classes based upon the means employed to work the various functions controlled from the interlocking machine. In a mechanical interlocking the functions are connected to the levers by pipe and sometimes, in the case of signals, by steel wire. The electro-pneumatic type of interlocking makes use of compressed air to work the switches and signals, and the movement of these functions is controlled by electro magnets, the same as with the block signals of this type of apparatus. In the electric interlocking system the signals and switches are worked by direct current obtained from generators, or from storage batteries, the switches being worked by motors and the signals by motors or by solenoid coils.

With the mechanical interlocking the connections between the levers and the signals, switches or locks are of one inch pipe, and are run from the lever to the signal or switch to be worked. To prevent the pipe from bending, carriers are placed every 7 feet apart, and turns or changes in direction of the line are made by means of cranks arranged on

The pipe-run on the other side of the tower.

suitable foundations. Changes in the length of the connections are taken care of by means of compensators, which must be put midway between the lever and the end of the pipe line. One switch, or in the case of a crossover, two switches may be



A dwarf signal at a mechanical interlocking plant.

worked by one lever. Another lever must be used to work the switch point lock by which the switches are locked and held after being moved into proper position by the lever from which they are worked. The signals in the rear of the switches are known

as home signals for movements on a line with the direction of traffic, and are placed on high signal poles. Movements on main lines in the reverse direction of traffic, and on or from sidings and yard tracks are placed on short posts about 18 inches above the top of the tie, and are known as dwarf

A "Clear" signal.

signals. Distant signals placed in the rear of the home signal a distance in excess of the braking distance for the maximum speed allowed, are used to repeat the proceed indication of all of the home signals, and being further away than can advantageously be worked by mechanical connections, are power operated, being worked by a motor taking

current from a battery of 16 cells placed approximately at the base of the signal pole. Each signal of an interlocking should be worked by a separate

Showing method of transmitting motion from pipe-run on the ground to signals on a bridge.

lever as giving greater reliability in operation, and relieving the signalman of the necessity of checking the position of the switch levers, to insure that the desired route is set before a signal is cleared. For

this reason, the use of selectors by which one or more signals are operated by one lever, is being given up. For interlocking plants, where the switches are reasonably close to the tower, and there is ample space in which to run the connections with

An interlocked double-slip switch.

good drainage, a mechanical machine is considered as reliable and safe working, besides being the most economical to maintain of any that are now in general use.

The electro-pneumatic interlocking system uses

compressed air at 75 to 100 pounds pressure to work the switches and signals. One or two switches may be worked by one lever. The unlocking, the moving and the relocking of a switch are all performed by the switch movement, which is operated by a piston moving in a cylinder to which compressed

An interlocking switch, showing a facing point lock.

air is admitted when the switch is to be moved. The indication by which assurance is given at the machine, that the movement has completed its stroke, is given by contact springs attached to the movement, a separate circuit being used to lock the lever and prevent the completed movement being made until the indication has been received at the

machine. The signals are of the same form and type as used for the electro-pneumatic block signals. An indication circuit is provided to insure that the signal has been returned to the stop position before the signal lever may be placed normal and un-

An interlocking derail, showing a switch and lock movement.

lock the other levers of the route governed by the signal.

Where an electro-pneumatic interlocking is installed on a line equipped with electro-pneumatic signals, the compressed air supply may be obtained

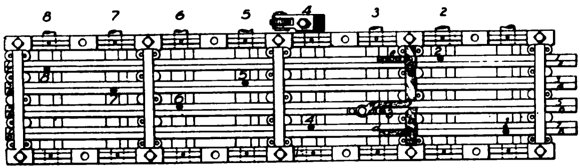
from the main pipe in use at such point, but in the case of isolated plants an air compressor equipment in duplicate must be put in. If steam may be obtained from a nearby power station, steam operated

A small interlocking tower. Governs a single track crossing.

air compressors are generally used, but if not, gasoline or oil engines should be put in for the purpose.

The all electric type of interlocking is the one of most recent development. With this type, an elec-

tric motor is used to work a switch or a signal. Several mechanisms have been designed to work these functions, but the most common is that where the high speed of the motor armature is reduced by means of gears to the slow speed required to turn an escapement crank which in turn unlocks a switch, moves the switch and relocks it. A valuable feature of such a system is the changing of the motor into



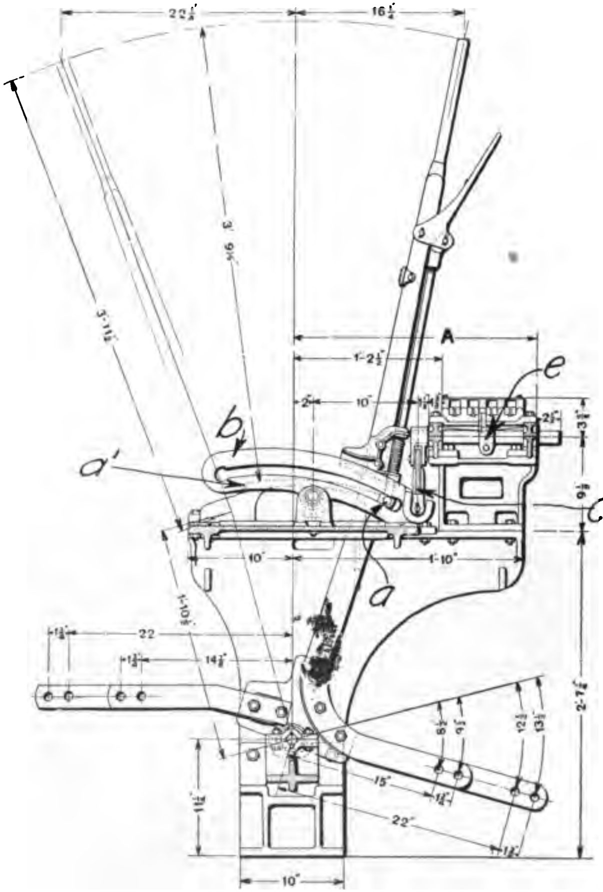
Principle of interlocking for Saxby & Farmer machines. In the diagram lever 1, when reversed, i. e., moved to the right, will lock lever 2 in its normal position if lever 3 is reversed.

a generator by reversing the connections, after the switch has been moved, and using the current so generated to energize the indication magnets to release the switch lever. A saving is thereby effected in wire connections and current is supplied to these wires to give the indication only after the movement of the switch has been completed. The giving of an indication by this means is known as the

"dynamic" method as distinguished from the battery form of indication. So also with the signal movement the restoring of the mechanism to the normal position is made to generate current to give the indication at the interlocking machine and release the lever only after the signal has been returned to the stop position.

The power equipment for the electric interlocking is less expensive than for the electro-pneumatic, as the movement of a switch or signal is completed in one or two seconds, after which the current is shut off until the switch is again to be moved. It is therefore possible to charge storage batteries and run a plant of moderate size for four days or a week with but one charging of the batteries, which may be of comparatively small size, as may also be the size of the generator and gasoline engine with which current is obtained to charge the batteries.

In the operation of a switch from the lever of an interlocking machine, it is essential for safe working that a switch must not be thrown under a train, whether the train be running through the switch in a facing or a trailing direction. To prevent this being done detector bars are made use of. These bars are formed of 2½x⅜ or ½ inch steel, arranged



Sectional diagram and principal dimensions of Saxby & Farmer interlocking machine.

on edge on the outside of the head of the rail. In its normal position, with the top edge of the bar below the top of the rail, the bar is not touched by the wheels of passing trains. The bars are held in position by means of clips and links, so arranged that when the bar is moved, the top of the bar is raised about ¾ of an inch above the top of the rail. If a wheel is on the rail above the bar, the bar will be prevented from changing from one position to the other. By connecting the bar to the movement working or locking the switch, the switch cannot be unlocked and thrown when there is a wheel passing or standing on the rail and projecting above the detector bar.

With the 100 pound rails with wide heads, now commonly used, all wheels of a train do not project over the top of the detector bar sufficiently to insure in all cases against the bar being thrown under a train, and it is now becoming customary to use electric locking of the switch levers as a substitute for the detector bars. This locking may readily be performed by making the section of track, in which the switch or switches it is desired to protect are located, into a track circuit and controlling the lock on the switch lever by this cir-

cuit. If the track is occupied the lever will be locked and cannot be thrown. This method has been found to be more effective than detector bars, as if the lever is pulled when it should not be, the lock will take the strain much better than a bar which might slip by the edge of a wheel or even be broken by the wheel, allowing the switch to be

An electro-pneumatic interlocking machine.

changed under the train. By arranging an indicator to show when a section of track is occupied, and connecting it to the circuit controlling the lock on the lever, an indication is given of the approximate position of a train that may be occupying any part of the track within the limits of the interlocking, and the signalman will know, without trying a lever, whether or not the lever may be

moved and the switch changed. A number of relays are required for the circuits of even a small plant.

Electric locking, although preventing the changing of the switch after a train has run on the track circuit, thereby shunting the relay and locking the lever, is not effective in holding the lever when the track circuit section is unoccupied. It has at times occurred that the signalman, after setting up a route and clearing the signals for an approaching train, has improperly changed the signals to indicate stop and opened a switch changing the route immediately ahead of the train, with the occasional result of derailing the train or causing it to come into collision with another. To guard against the signalman making a mistake of the kind, and an engineman claiming, in case of an accident, that the signal had been taken away from him, a system of approach locking has been devised, which locks the route for which a signal has been cleared, from the time the train arrives at the track circuit in the rear of the distant signal until the head end of the train passes a home signal and will have run on the switch locking track circuit, locking the switch and preventing a change of the route. In addition

to forming an approach lock on the signal lever, the arrangement is made to serve as an indicator an-

A group of relays and storage batteries governing automatic signal circuits.

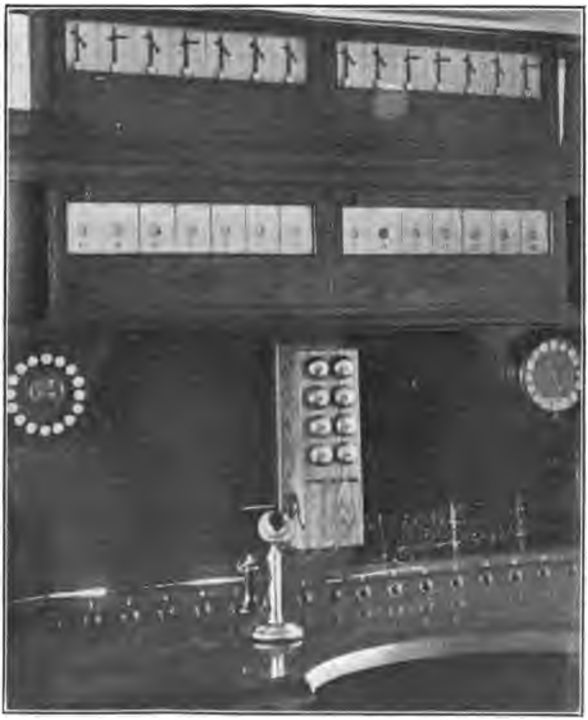
nouncing the approach of a train and calling the attention of the signalman to the fact that the

signals should be cleared for the oncoming train to proceed.

With the increase from double to 3 or 4 main tracks, the number of signals required at an interlocking to indicate the route set has greatly increased, and with the increase in speed the necessity has arisen of indicating to an engineman the speed at which the train may run, in addition to the route the train is expected to take. To enable an engineman to run at speed through an interlocking, it is necessary that a distant signal indication, in addition to the home signal, be given for each route on which limited and normal speeds may be run.

With the ordinary two-position signal, which in the horizontal position indicates stop or caution, and in the downwardly inclined position indicates proceed, three home signal arms will be required on each pole, and in addition two distant signal arms, one to repeat the indication of the next signal in advance on the normal speed track, and the other the indication of the next home signal in advance on the limited speed route. This would call for the installation on these signals of five arms, which is objectionable from the difficult and expensive construction involved, and from the fact that it is

confusing to the enginemen to have to observe so many arms and lights, and mistakes may result. The practice was therefore begun a number of years ago of dispensing with the distant arms and



A group of indicators in a tower. By means of these indicators a tower-man is enabled to note at a glance the positions of trains on the tracks governed by his machine.

making the home signal arm travel indicate proceed and to use the 45 degree or middle stroke position of the arm to indicate caution when repeating the stop indication of the next home signal in advance. With this arrangement of signals three arms would be the maximum required for a single pole, and in addition to indicating routes, speeds could also be indicated by having the top arm cleared only for the main line or normal speed route, the second arm for the limited speed route to another track with traffic, and the third, the lowest arm, to indicate proceed for any route whether there was a signal in advance and whether or not the track was occupied.

In using the arm in the vertical position to indicate proceed, it was found that the arm was not as easily distinguishable as when occupying the 60 degree position, and it was recommended that the arm be moved upwardly from the horizontal position to give the cautionary and proceed indications. This was merely a return to the arrangement used in the early days of railroading, and now used in a modified way in Germany. In addition to making the signal more distinguishable, greater safety in operation will result from moving the signal up-

wardly from the horizontal position, as should there be an accumulation of ice or snow on the parts or the mechanism become disconnected from the sig-

An electric interlocking machine.

nal, the weight of the spectacle and blade would act to return the signal to the position to give the stop indication. On account of these advantages the Railway Signal Association has recommended,

and a number of roads, among them the New York Central and the Boston & Albany, have adopted this new universal system of signaling, whereby the arms move upwardly to give the caution and proceed indications, with the 45 degree position indicating caution, the vertical position proceed, and with the upper arm governing movements to be made at normal speed, the second arm of a signal to govern movements to an adjacent track at limited speed and with traffic, and the third arm for a movement to any route for which the switches may be set. The lights at night on a home signal giving a "Stop and stay until authorized to proceed" indication are arranged in a vertical line; on an automatic signal which, when in the stop position indicates "Stop and then proceed with caution," the lights are diagonally arranged on the pole and with the train order signal which indicates "Stop within defined limits, there are orders for you," the lights are horizontally arranged, at least two lights being used on each signal irrespective of the number of arms on the pole.

Up to the present time block and interlocking signal systems for surface railroads are designed and operated on the assumption that the engine-

man will obey the indications of the signals and safe working will result. However, it is a fact that enginemen, like other human beings, occasionally make mistakes, go to sleep on duty, forget what they are doing and instead of always observing the caution indication of the distant signal and the stop indication of the home signal, will pass the home signal without stopping, with the possibility of a derailment or a collision occurring with another train. In the endeavor to perfect a satisfactory cab signal and an automatic stop or train control device, which will compel the engineman to obey a stop signal indication, a number of devices and forms of apparatus have been patented and the attempt made, through public opinion, to force the railroads to use one or more of these for the safeguarding of traffic. Up to the present time, a number of train control devices have been given a trial in actual service, but not one is in general use on a surface railroad in the United States, although they have been introduced to a limited extent in England and are in successful use on roads having special traffic, such as the elevated line in Boston and on the subway and the Hudson terminal lines in New York. One automatic stop system has

been tested on a western road and is being officially observed by the Block Signal and Train Control

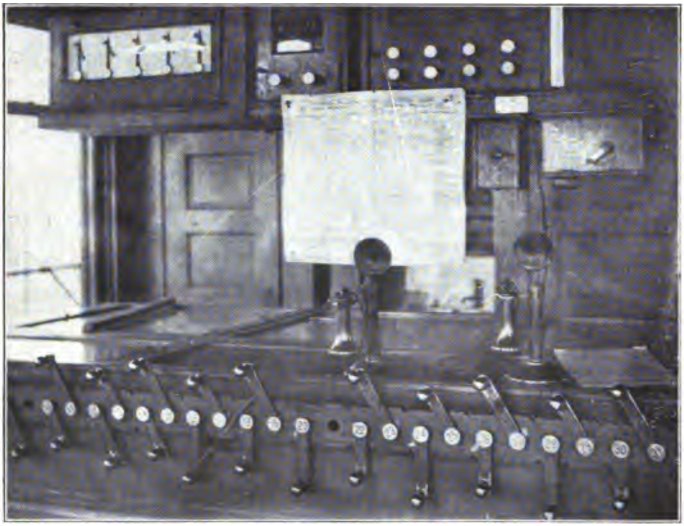
A double automatic signal location on single track.

Board of the Interstate Commerce Commission, but has not yet been in use long enough to show what

it will do under all conditions of weather. So many of these devices have been brought out by men who would save millions for railroads by preventing accidents, but which are so impracticable and impossible of operation, a committee of the Railway Signal Association has submitted to its members for adoption a set of requisites of installation for these devices which should be complied with before a given device may be considered as fulfilling the requirements for the safe and proper operation of trains.

The rules under which signals are used and maintained are a very important feature in the operation of the railroad and have a great deal to do with the successful use of the signals. Rules governing the operation and use of the different types of signals and signal systems in service on a given road, must be prepared for and observed by the men in the operation of the trains. In a general way, rules should be framed governing the observance of and the use of the various types of signals, the rules for each class of employes, those for the train and engine crews, and those for the signalmen being worded to cover the exact duties to be performed by each. The rules should also cover such fea-

tures as the definitions, types of signals, signal aspects and indications, principles of signal locations, general rules to be followed in the use of all classes of signals and detail rules for the use and



Section of electro-pneumatic interlocking machine, showing also indicators and train announcing devices.

observance of particular systems and special signals.

The matter of estimates for, and the cost of signal work, is a most important one and must receive especial attention on the part of the signal engineer.

In nearly every instance, before work is authorized, an estimate of the cost must be made by the signal engineer, and where contracts are to be let an engineer's estimate should be made as a check of the bids to be made by the contractors. For the parts to be seen by the casual observer, and even to many operating officials, signal work is considered as costing in proportion more than any other part of the equipment of a road. The reason for this is largely due to the expensive materials used, the copper and rubber in insulated wires, and the finely finished mechanisms required for the interlocking machines, signals and relays. The electrical attachments and adjuncts to an ordinary mechanical interlocking very nearly double the cost of the installation without any apparent increase in the equipment, so far as is observed by those not familiar with the details of the installation. The criticism has been made that these additional safeguards might profitably be dispensed with and the money used in extending the simpler forms of signal protection. While possibly this may be true in exceptional instances, such practice will not be advisable until operating officials and the public recognize that the enginemen and the sigalmen should be so

trained that they will perform their duty regularly, properly and without fail and that it is not necessary to so perfect the signal system that wrong movements and collisions must be prevented irrespective of whether the men do as they should or

A typical signal bridge.

fail to act in accordance with the indications given by the signals.

The number of signals now in use, and the forces employed in installation and maintenance are so large the signal department of a road is becoming more

and more specialized and increasing in importance as this occurs. The signal department on various roads is organized in almost as many different ways as there are roads, but as with many other departments they are generally arranged on a departmental plan for roads having comparatively few signals, and on a divisional basis on large roads which are well equipped with signals. In the departmental organization the signal engineer is usually in complete charge of the department, having control of the construction and maintenance forces, and acting in an advisory capacity on signal matters to the general manager, the general superintendent or the chief engineer, as the case may be. The signal engineer has charge of the stock carried, makes requisitions for signal material, has charge of the signal accounts, causes investigations to be made of signal failures, reporting to and conferring with the operating department in cases where accidents have occurred and the signals are involved.

With a divisional organization the signal work on a division is usually put in charge of a signal supervisor, who reports to the division superintendent, and in matters pertaining to the maintenance of signals, and sometimes in the installation of new

signals, acts practically as the signal engineer for the division. The signal engineer on such roads then becomes a staff officer, acting in an advisory capacity to the general manager, general superintendent or chief engineer, as may be arranged. He is usually charged with the making of signal standards, making or approving plans for new installations and, in many cases, contracting for and supervising new installations that are made.

The signal engineer, to be successful in his work, must be a man with an extended knowledge of the details of the business, and have exceptional qualifications in the matter of handling men, good business ability, particularly in accounting matters, be well posted on train operation and the movement of trains at special points. He should be able to advise his superior officer in regard to operating practice and to write or to revise signal rules. He must be well posted on track work, for when a switch is connected to and worked from an interlocking, the signal department becomes responsible for the adjustment of the switch.

The signal engineer should have a knowledge of paints and painting, cements and concrete work, blacksmithing, pipe fitting, be a machinist as well

as a draftsman, be capable of making designs of mechanical apparatus and constructing the same, and lastly and almost of the most importance he should be an electrical engineer. There is not, to my knowledge, a department of railroad work in which the men are required to have an expert knowledge of their own, as well as of the work of other departments, as is the case with the signal department, and with the advance in the art and science of signaling, the work of the signal engineer will increase rather than decrease, and he will be given that recognition which the work he is called upon to perform most properly entitles him to.